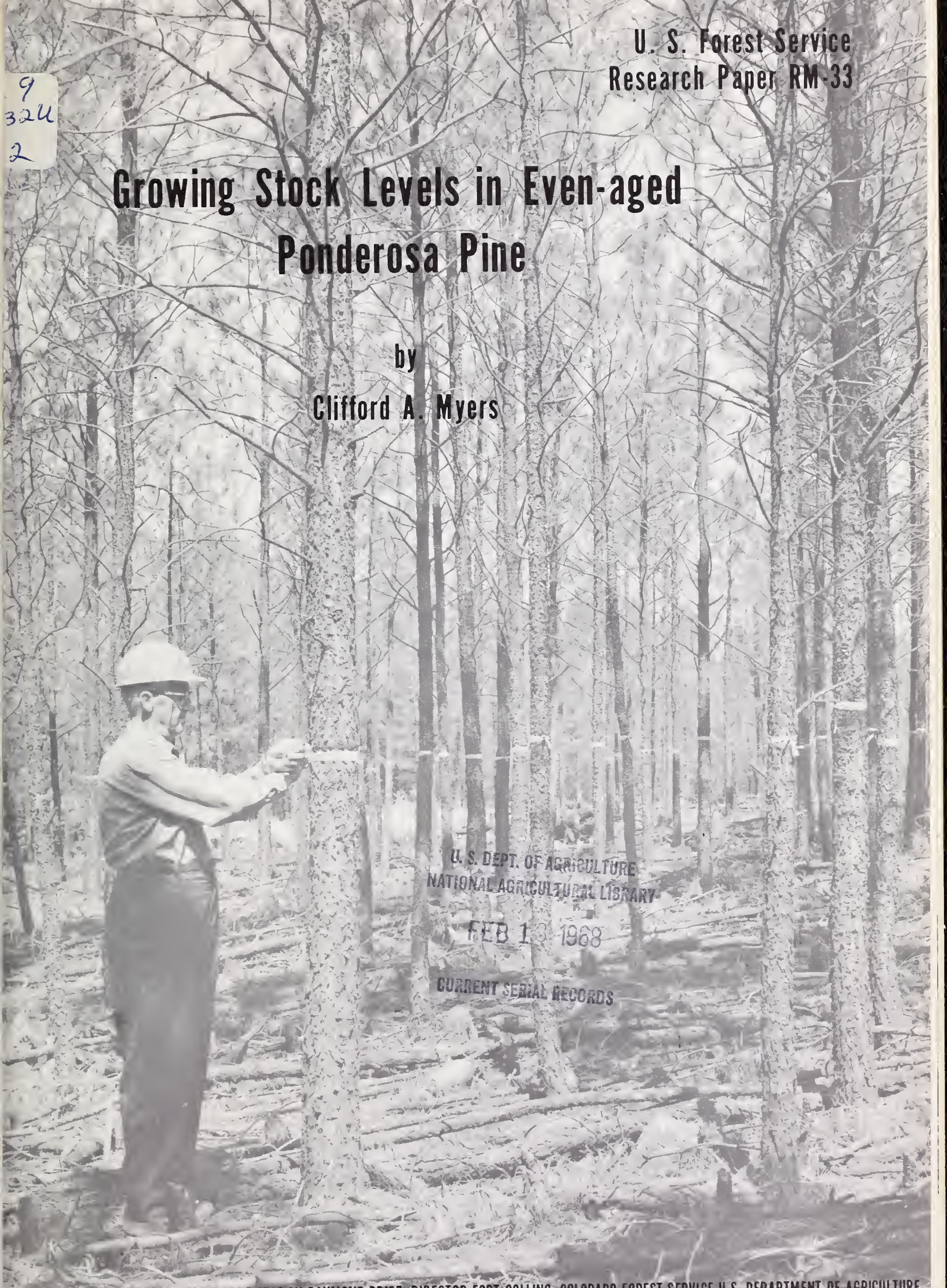
U. S. Forest Service
Research Paper RM-33

Growing Stock Levels in Even-aged Ponderosa Pine

by

Clifford A. Myers



MOUNTAIN FOREST AND RANGE EXPERIMENT STATION-RAYMOND PRICE, DIRECTOR-FORT COLLINS, COLORADO-FOREST SERVICE-U.S. DEPARTMENT OF AGRICULTURE

U. S. Forest Service Research Paper RM-33 1967

GROWING STOCK LEVELS IN EVEN-AGED PONDEROSA PINE

by

Clifford A. Myers, Principal Mensurationist

Rocky Mountain Forest and Range Experiment Station[1]

[1] Central headquarters maintained in cooperation with Colorado State University at Fort Collins.

Growing Stock Levels in Even-aged Ponderosa Pine

by

Clifford A. Myers

Growth of the most widely distributed pine in North America is under joint study by the western Forest and Range Experiment Stations of the U. S. Forest Service. Young, even-aged ponderosa pine (Pinus ponderosa Laws.) stands are being examined over a wide range of tree sizes, stand densities, and site index. The single plan that coordinates activities of the four Stations is an example of how the growing stock problem can be handled for a widely distributed species. The wide range in treatments should provide data needed to answer the questions that arise in evaluation and application of multiple use management of ponderosa pine forests.

Intensified management of ponderosa pine for wood products depends on control of growing stock. Such control will permit actual yields of the coast form of ponderosa pine to approach its high potential. The interior form of ponderosa pine occurs in areas of lower site quality, and much of it is subject to stagnation. Saw-log rotations of some dense, young stands may be shortened 60 to 80 years by thinning. Growing stock can be controlled most effectively if stand productivity can be forecast for various combinations of such factors as tree size, stand density, and site quality.

Thinning studies, once conducted in almost all ponderosa pine areas, have not provided all the information needed to prescribe growing stock goals. Results from thinned plots have been useful in planning past management and research activities but deficiencies have become more apparent as conversion to managed stands continues. There was usually no attempt to test the low-reserve densities that may be tomorrow's standard. Data were often not complete enough to provide for changes in products or merchantable sizes. Remeasurements were sometimes made at such long intervals that the growth information did not indicate results attainable from the frequent cuttings of today. Thinning studies were sometimes planned with economic restrictions as part of the design. For example, thinning frequency and intensity were sometimes determined by the idea that only one thinning was practicable during a rotation. Current work is intended to obtain growth information over a range of stand and site conditions, and with a minimum of operational restrictions. Results are expected to provide useful guides for a variety of management objectives.

Much necessary information on the management of ponderosa pine will be obtained from satellite studies. These additional studies, some of which will be done on the growth plots, will cover such work as (1) costs of cultural operations, (2) effects of stand density on tree and wood quality, (3) effects of slash and ground vegetation on soil moisture and tree growth, (4) relationships between stand density and the production for forage and other forest products, and (5) growth of individual trees as related to various tree and stand factors.

General Design

Study design was determined by the questions to be answered and by the nature of available stands. The following problems and objectives were considered in deciding what would be done.

1. Lack of areas uniform in site quality and stand characteristics that are large enough for installation of compact designs such as randomized blocks or Latin squares.
2. Probability that treatments would be modified by porcupines, insects, or other agencies.
3. Danger that some plots of a design would be destroyed before completion of the study.
4. Interest in the response over a range of possible conditions, rather than in certain comparisons selected in advance.
5. Interest in methods for the prediction of growth and yield for various possible management objectives.

Locations

Five areas of ponderosa pine forest were selected for study and assigned to the participating Experiment Stations (fig. 1). These five "provinces" differ in several respects. Physiography ranges from the uplift of the Black Hills to the Coconino Plateau of Arizona and the mountains of California. Some provinces are without precipitation for of the summer; other provinces receive most of the annual precipitation during the growing season. Ponderosa pines of the five provinces exhibit a number of genetic differences, and may differ genetically in factors that affect wood production.

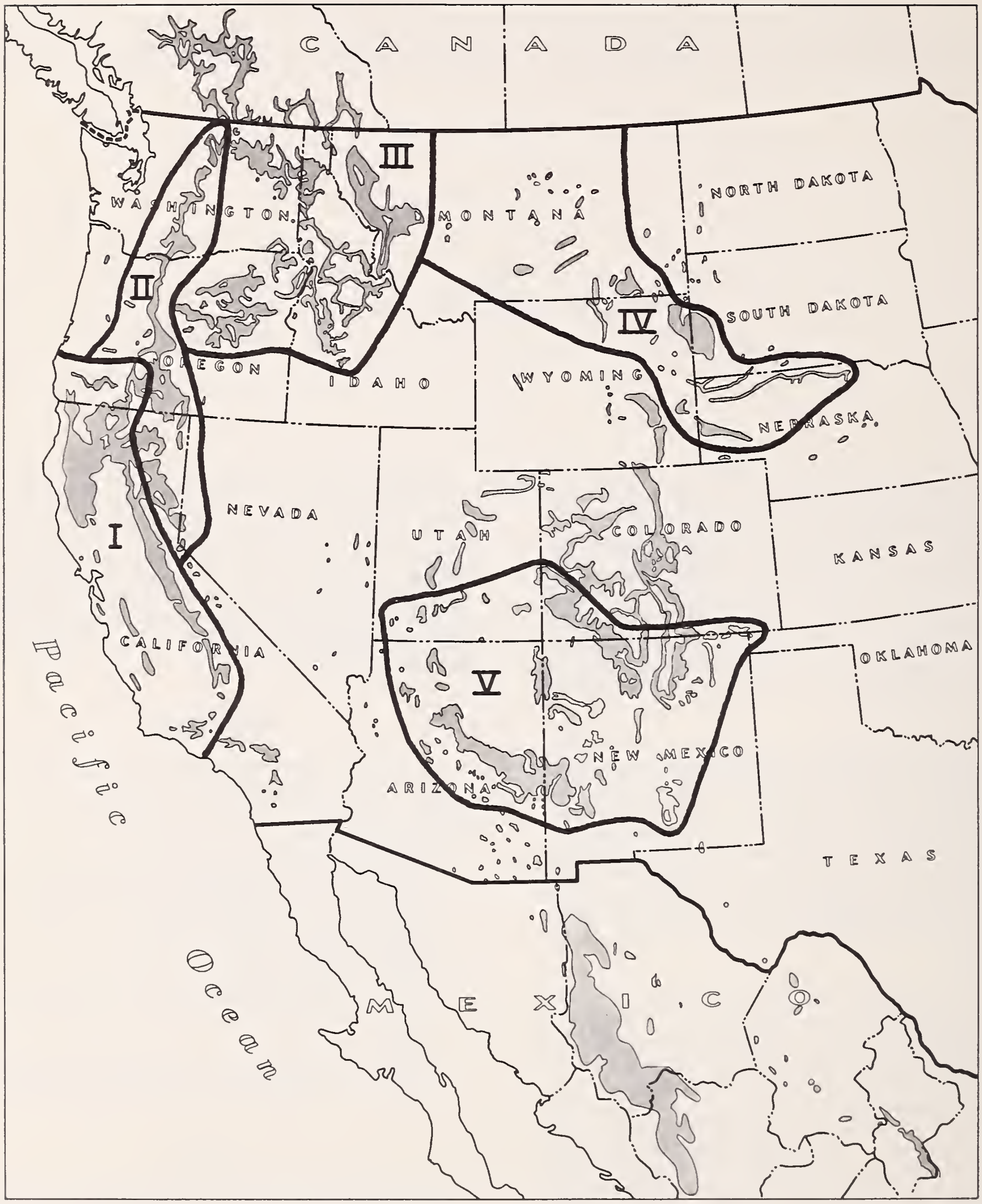


Figure 1.--Province boundaries for study of levels of ponderosa pine growing stock (map adapted from Intermountain Forest and Range Exp. Sta. Misc. Pub. 12).

Within each province, a variety of conditions in even-aged stands are selected for study. As many of the following tree size classes as are available will be sampled:

Class	Average d.b.h. after thinning (Inches)
Small saplings	0.6 - 2.0
Large saplings	2.1 - 4.0
Small poles	4.1 - 8.0
Large poles	8.1 - 12.0

Groups of six plots each will be established to sample areas of different site quality within each size class. As a minimum, each Station will establish plots in areas of low, average, and high site index for their province. In one province, the range of site index of suitable stands is so narrow that only one 10-foot site index class will be studied.

Plots are to be at least 0.25 to 0.5 acre for small saplings, and 0.5 to 1.0 acre for other size classes. Each plot will contain healthy, even-aged stands of ponderosa pine. Tree size, stand density, and site index of each plot are to be as uniform as can be selected.

Uniform areas large enough to contain compact blocks with all the desired cutting treatments cannot be found for most size-site combinations. Six plots, one set of the six cutting treatments defined below, will usually be scattered irregularly over a limited area wherever suitable conditions exist.

Each Station is studying a variety of site and stand conditions, so results from each province can be analyzed separately, if necessary.

Initial Treatments

Stand densities to be retained after thinning are specified as a series of growing stock levels. These levels are defined by relationships between basal area and average stand diameter (table 1, fig. 2). Numerical designation of the level assigned a plot is the basal area per acre that will remain after thinning when stand diameter is 10 inches or more. For example, a plot thinned to growing stock level 80 and an average diameter of 5.5 inches will have 51.6 square feet per acre. Number of trees per acre is used when diameters are so small that basal area is not a convenient measure. Experience has shown that stands can be marked to a density based on diameter after thinning, with only minor changes in marking needed after actual average diameter has been computed. No attempt is made to obtain exactly the basal areas specified. Deviations from the values of table 1, however, have usually been much less than the ± 2.0 square feet allowed.

Derivation of density levels

Values in table 1 and figure 2 were based on published and unpublished results of thinning experiments. Most available data were from plots in site index class 60, so comparisons were restricted to plots in this class. Pairs and groups of plots provided information on the residual basal area that appeared best for each average stand diameter represented. Growth per acre in cubic volume to a 4-inch top and probable length of saw-log rotations guided each selection of "best." Selected basal areas were plotted over corresponding stand diameters. Almost all points could be connected by the curve labeled 80 in figure 2. Other curves were drawn above and below the curve for level 80 at fixed percentages of the basal areas of level 80. The percentages were computed from basal area at average diameter of 10.0 inches divided by 80.

Basal areas and average stand diameters were used as joint measures of growing stock for both accuracy and convenience. Basal area and average diameter are highly correlated with growth in diameter, basal area, and volume. Basal area, with point sampling, is a quick, easy way of getting results of this study applied on the ground.

Application of Density Levels

One plot of each group of six in a site-size combination is thinned to the density considered best for the average site index of the province. This density is selected on the basis of experience, temporary plots, and past thinning studies. Two or three plots are thinned to lower densities and two or three have higher residual density. The operation is primarily a low thinning; the smallest trees and rough dominants are removed.

Available evidence indicates that the highest and lowest densities selected will be beyond the desirable range of growing stock for all alternatives of timber production (figs. 3, 4, and 5). In one province, plots were established with growing stock levels of 20, 40, 60, 80, 100, and 120. In another province, levels of 30, 60, 80, 100, 120, and 150 are under test. About three groups of six plots each will be established in each site-size combination of a province.

Several operations are performed after thinning is completed. Merchantable pieces or pulpwood bolts, whichever is smaller, are removed from the plots. Other slash is lopped and scattered. Dead branches are pruned to head height for convenience in measurements. Live branches remain uncut so that the effect of stand density on wood quality and on pruning costs can be evaluated. Ground vegetation is allowed to develop normally so forage production can be studied. Reserve trees were sprayed with 2 percent emulsifiable DDT in one province because the probability of Ips buildup was great.

Field Measurements

Certain items are to be measured at least every 5 years. These include the usual tree measurements such as diameter breast high and total height. Crown classification, crown dimensions, and information on tree quality are obtained for use in future satellite studies. Crown classification is determined by S.A.F. crown class. Crown dimensions

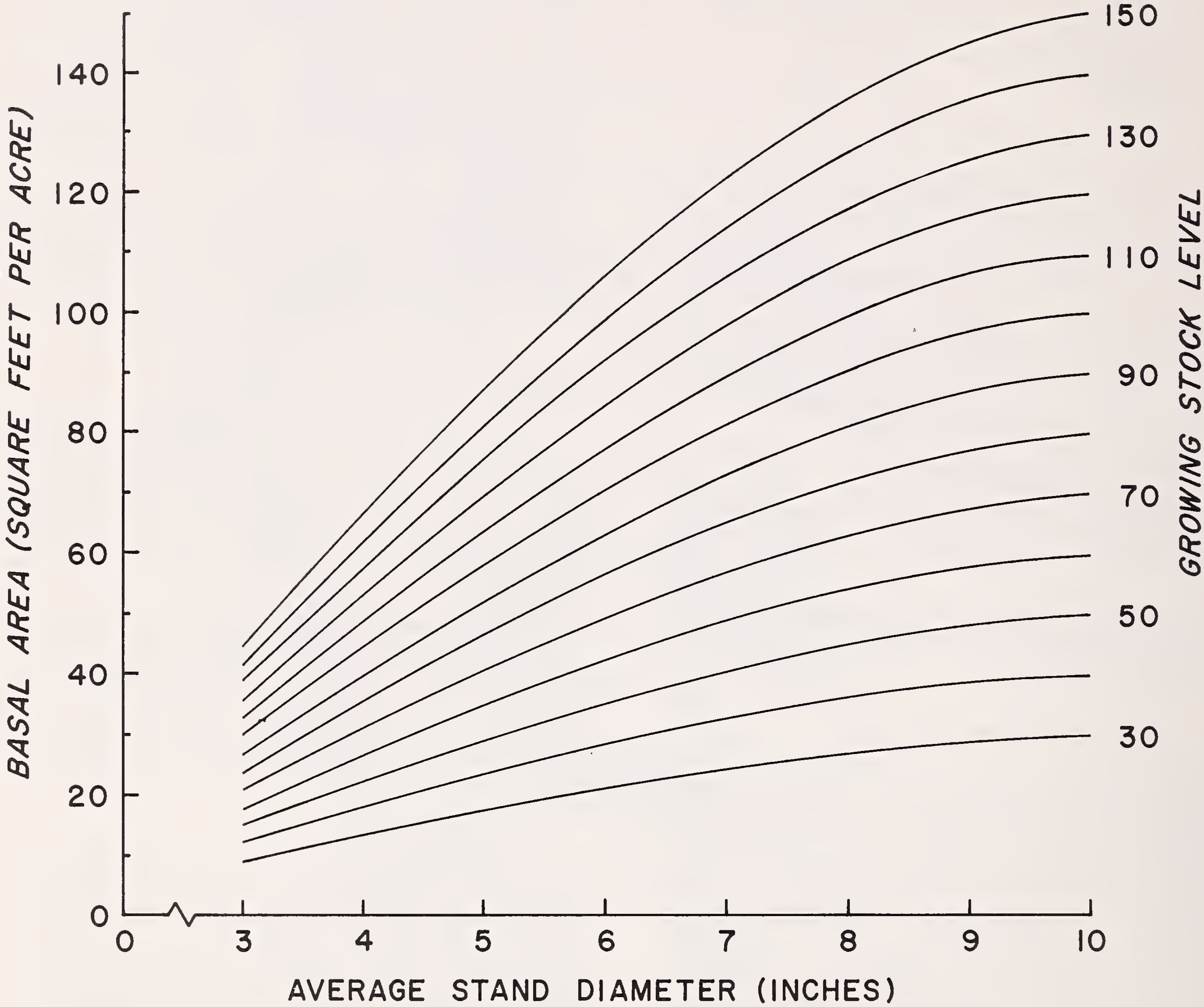


Figure 2.--Basal area after thinning in relation to average stand diameter. Standard levels of growing stock for ponderosa pine.

Table 1.--Growing stock levels for even-aged ponderosa pine. Basal areas after intermediate cutting in relation to average stand diameter

Average d.b.h. after thinning (Inches)	Density level																
	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
	Square feet																
1.0	0.9	1.4	1.8	2.3	2.8	3.2	3.7	4.2	4.6	5.1	5.6	6.0	6.5	6.9	7.4	7.9	8.3
1.5	1.8	2.8	3.7	4.6	5.6	6.5	7.4	8.3	9.2	10.2	11.1	12.0	13.0	13.9	14.8	15.7	16.6
2.0	3.1	4.6	6.2	7.7	9.2	10.8	12.3	13.8	15.4	16.9	18.4	20.0	21.5	23.1	24.6	26.1	27.7
2.5	4.4	6.6	8.8	11.1	13.3	15.5	17.7	19.9	22.1	24.3	26.6	28.8	31.0	33.2	35.4	37.6	39.8
3.0	5.9	8.8	11.8	14.8	17.7	20.6	23.6	26.6	29.5	32.4	35.4	38.4	41.3	44.2	47.2	50.2	53.1
3.5	7.4	11.1	14.8	18.5	22.2	25.9	29.6	33.3	37.0	40.7	44.4	48.1	51.8	55.5	59.2	62.9	66.6
4.0	8.8	13.2	17.6	22.0	26.4	30.8	35.2	39.6	44.0	48.4	52.8	57.2	61.6	66.0	70.4	74.8	79.2
4.5	10.2	15.4	20.5	25.6	30.8	35.9	41.0	46.1	51.2	56.4	61.5	66.6	71.8	76.9	82.0	87.1	92.2
5.0	11.7	17.5	23.4	29.2	35.0	40.9	46.7	52.5	58.4	64.2	70.0	75.9	81.7	87.6	93.4	99.2	105.1
5.5	12.9	19.4	25.8	32.2	38.7	45.2	51.6	58.0	64.5	71.0	77.4	83.8	90.3	96.8	103.2	109.6	116.1
6.0	14.2	21.2	28.3	35.4	42.4	49.5	56.6	63.7	70.8	77.8	84.9	92.0	99.0	106.1	113.2	120.3	127.4
6.5	15.3	22.9	30.6	38.2	45.8	53.5	61.1	68.7	76.4	84.0	91.6	99.3	106.9	114.6	122.2	129.8	137.5
7.0	16.4	24.6	32.8	40.9	49.1	57.3	65.5	73.7	81.9	90.1	98.2	106.4	114.6	122.8	131.0	139.2	147.4
7.5	17.3	25.9	34.6	43.2	51.8	60.5	69.1	77.7	86.4	95.0	103.6	112.3	120.9	129.6	138.2	146.8	155.5
8.0	18.1	27.2	36.2	45.3	54.4	63.4	72.5	81.6	90.6	99.7	108.8	117.8	126.9	135.9	145.0	154.1	163.1
8.5	18.8	28.3	37.7	47.1	56.6	66.0	75.4	84.8	94.2	103.7	113.1	122.5	132.0	141.4	150.8	160.2	169.6
9.0	19.4	29.1	38.8	48.4	58.1	67.8	77.5	87.2	96.9	106.6	116.2	125.9	135.6	145.3	155.0	164.7	174.4
9.5	19.8	29.6	39.5	49.4	59.2	69.1	79.0	88.9	98.8	108.6	118.5	128.4	138.2	148.1	158.0	167.9	177.8
10.0+	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0	110.0	120.0	130.0	140.0	150.0	160.0	170.0	180.0

Figure 3.--Some reserve densities are expected to be greater than desired for any objective of multiple use management. This 150-level plot had an average stand diameter after thinning of 4.7 inches and 81 square feet of basal area in about 680 trees per acre.

measured include proportion of tree length in live crown, and amount of crown circumference with live branches. Tree quality descriptions include amount of lean, presence of dwarf mistletoe or other disease, porcupine damage, and other items that can reduce vigor or merchantable volume. Most Stations plan to obtain cubic volumes both from volume tables and from optical dendrometer readings.[2,3] A complete soil profile description will be obtained on each plot.

[2] Grosenbaugh, L. R. *Optical dendrometers for out-of-reach diameters: A conspectus and some new theory.* Forest Sci. Monogr. 4, 47 pp. 1963.

[3] Mesavage, Clement. *Aids for using Barr and Stroud dendrometers.* Soc. Amer. Forest. Proc. 1964: 238-244.

Figure 4.--This plot will be rethinned periodically to the appropriate basal area of growing stock level 80. These 336 trees averaged 5.1 inches in diameter immediately after initial thinning to 48 square feet of basal area per acre.

Figure 5.--Low reserve densities are expected to reduce wood production below desirable levels. Thinning to growing stock level 30 left about 125 trees and 18 square feet of basal area per acre. The trees averaged 5.2 inches in diameter.

Subsequent Treatments

Each plot will be rethinned at least once to the basal area determined by stand diameter after rethinning and the growing stock level initially assigned. Reserve density of each plot will thus move down the appropriate column of table 1 as average diameter approaches 10 inches.

The interval between treatments has not been specified definitely. Most participants believe that a 10-year interval will be most informative. As a check, plots already established will be remeasured five full growing seasons after initial cutting. Periodic growth will be examined to see if a 5-year treatment interval should be adopted. Tentatively, all plots of the study will be re-treated at the same interval, or at intervals that are multiples of a base period.

Analysis of Data

If possible, final data from all five provinces will be analyzed as a unit to take advantage of the large sample size and wide range of variables measured. If a single analysis is not possible, the minimum number of sets of data necessary will be identified and analyzed. Not all Stations are establishing plots on the same time schedule, so preliminary results from single provinces will be available before combined analyses are made.

Multiple regressions will probably be a major part of growth analyses. Dependent variables will include periodic or periodic annual increases in average diameter, basal area, and volume in cubic feet. Independent variables will probably include average diameter, basal area, and site index. Regressions can be used to prepare yield tables and to predict the results of management with various levels of growing stock.[4] [5]

Some Stations may be so fortunate as to locate areas large and uniform enough to establish all the plot locations needed for compact experimental designs for one or more site-size combinations. In such cases, they will conduct additional analyses of their data to support the regression analyses. Factorial analysis of the form tree size x site index x density is suggested.[6] There is interest in interactions such as density x tree size and density x site index.

Duration of Study

It is estimated that there will be two thinning treatments, each followed by a 10-year period of growth. Plots in each tree size class should move to the next size class or beyond in 20 years. At that time, the results will be examined to determine if responses by plots initially in different size classes will overlap. For example, do small saplings that have grown into small poles currently exhibit the same growth response as small poles did at the beginning of the study? If so, the regressions obtained will describe existing and future stands, and the experiment can be terminated. If not, the study will be examined to determine if it should be continued in whole or in part for additional thinnings and growth periods.

Regardless of the ultimate decision on duration of the study, useful information will be available soon. Preliminary results on the effects of stand density and tree size on volume growth will be available 5 years after any plots are installed. Results will be improved as increasing numbers of plots complete measurement cycles of 5 and 10 years.

[4] *Clutter, Jerome L. Compatible growth and yield models for loblolly pine. Forest Sci. 9: 354-371. 1963.*

[5] *Myers, Clifford A. Yield tables for managed stands with special reference to the Black Hills. U. S. Forest Serv. Res. Pap. RM-21, 20 pp., illus. Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colo. 1966.*

[6] *Yates, F. The design and analysis of factorial experiments. Imperial Bur. Soil Sci. Technol. Comm. 35, 95 pp. 1937.*

Agriculture --- CSU, Ft. Collins

Myers, Clifford A.
1967. Growing stock levels in even-aged ponderosa pine. U. S. Forest Serv. Res. Pap. RM-33, 8 pp., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, 80521.

Growth of ponderosa pine is under study in a coordinated investigation by the four western Experiment Stations of the U. S. Forest Service. Response of combinations of tree size, site index, and stand density will be determined. Results will be used to make forecasts of yield for possible alternatives of management.

Myers, Clifford A.
1967. Growing stock levels in even-aged ponderosa pine. U. S. Forest Serv. Res. Pap. RM-33, 8 pp., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, 80521.

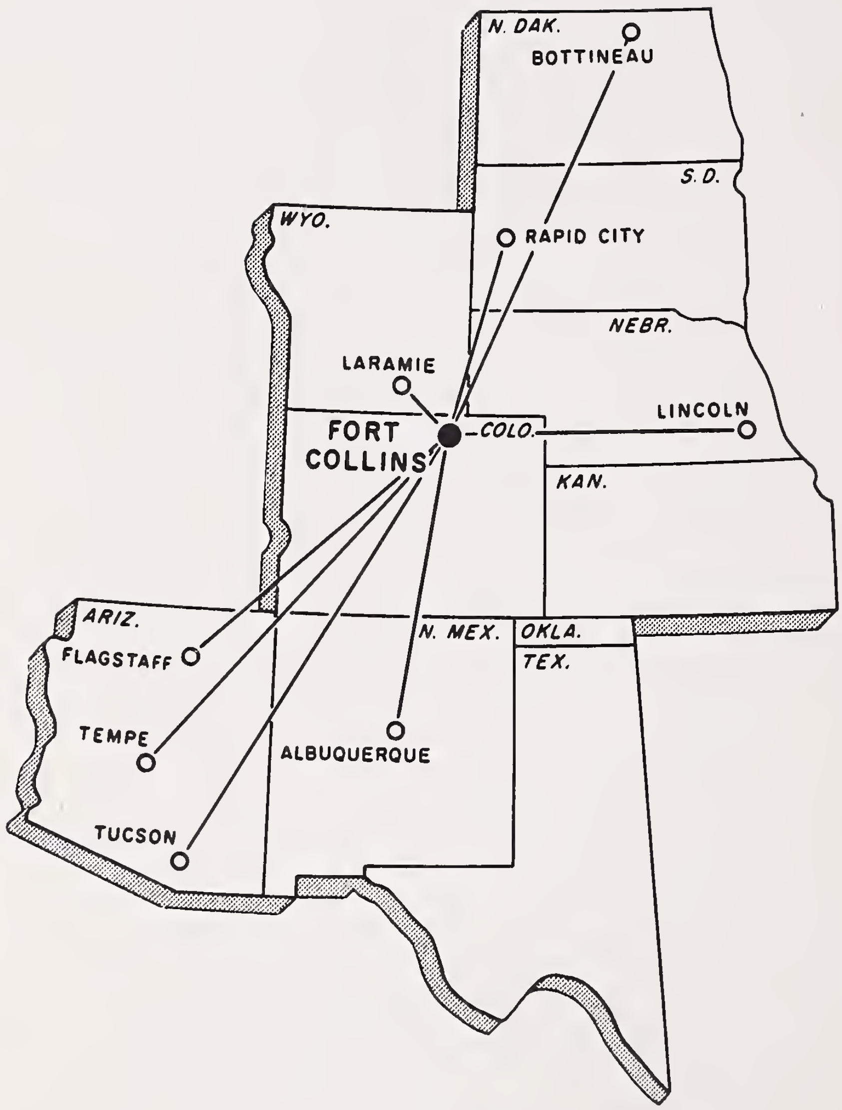
Growth of ponderosa pine is under study in a coordinated investigation by the four western Experiment Stations of the U. S. Forest Service. Response of combinations of tree size, site index, and stand density will be determined. Results will be used to make forecasts of yield for possible alternatives of management.

Myers, Clifford A.
1967. Growing stock levels in even-aged ponderosa pine. U. S. Forest Serv. Res. Pap. RM-33, 8 pp., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, 80521.

Growth of ponderosa pine is under study in a coordinated investigation by the four western Experiment Stations of the U. S. Forest Service. Response of combinations of tree size, site index, and stand density will be determined. Results will be used to make forecasts of yield for possible alternatives of management.

Myers, Clifford A.
1967. Growing stock levels in even-aged ponderosa pine. U. S. Forest Serv. Res. Pap. RM-33, 8 pp., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, 80521.

Growth of ponderosa pine is under study in a coordinated investigation by the four western Experiment Stations of the U. S. Forest Service. Response of combinations of tree size, site index, and stand density will be determined. Results will be used to make forecasts of yield for possible alternatives of management.


N. DAK.
BOTTINEAU
S. D.
WYO.
RAPID CITY
NEBR.
LARAMIE
LINCOLN
FORT COLLINS
COLO.
KAN.
ARIZ.
N. MEX.
OKLA.
TEX.
FLAGSTAFF
TEMPE
ALBUQUERQUE
TUCSON